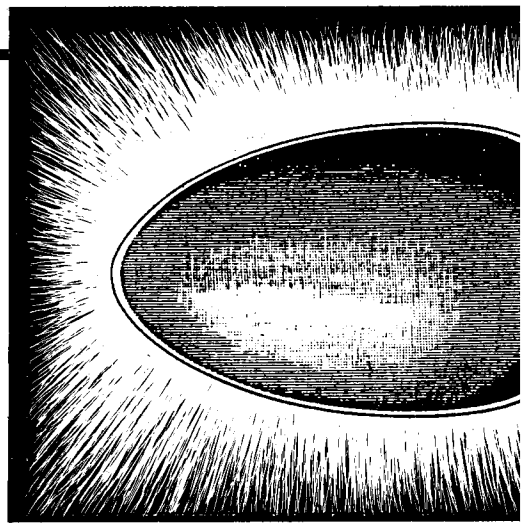
BACK BURNER



FRIEDRICH WÖHLER'S LOST ALUMINUM

By Benjamin M. Gimarc

Several years ago I was elected to serve a term as chairperson of the chemistry department at the University of South Carolina. As I moved my things into the new office, I looked through the desk drawers of my predecessor and came across an old cardboard box containing a folded piece of paper. Opening the first fold revealed a message, written by hand and iron-brown with age:

"Aluminum foil from Wöhler.
Don't open it in the wind."

Inside were a few small scraps of aluminum foil. Who was Wöhler, I wondered, and what was so important about these fragments of such a common material? I decided to look into it.

Today aluminum is almost part of the natural landscape. Indeed, aluminum is the most abundant metal in the Earth's crust. Its principal ore, bauxite, contains alumina (Al_2O_3) and is found on every continent.

Friedrich Wöhler (1800–1882) was a German chemist who studied medicine at Marburg and Heidelberg in Germany and chemistry under Berzelius at Stockholm, Sweden. About 1825 Wöhler began teaching at a technical school in Berlin. In 1831 he took a university post at Cassel, then moved to Göttingen where he stayed until he retired in 1880. He is best remembered for his preparation in 1828 of urea from ammonium chloride and lead(II) cyanate:

$$2NH_4Cl + Pb(OCN)_2 \longrightarrow 2H_2NCONH_2 + PbCl_2$$

ammonium chloride; lead(II) cyanate; urea; lead(II) chloride

This was the first synthesis of an organic compound from inorganic substances. The result was the first step in the downfall of Vitalism, the doctrine that the origin and phenomena of life are due to or produced by a vital principle, as distinct from purely chemical or physical forces. For example, it was believed that compounds characteristic of living organisms (such as urea—the principal compound in urine) could be made easily by animals but couldn't be synthesized in the lab. Wöhler's synthesis of urea was the first step in the unification of organic and inorganic chemistry as aspects of the same science.

In 1827, Wöhler was the first person to prepare aluminum metal in pure form and to describe its chemical properties. He made aluminum by reacting aluminum chloride with potassium metal:

$$AlCl_3 + 3K \longrightarrow Al + 3KCl$$

Potassium was a costly substance because it had to be produced electrolytically, using an electric current generated from other expensive chemicals in a voltaic cell.

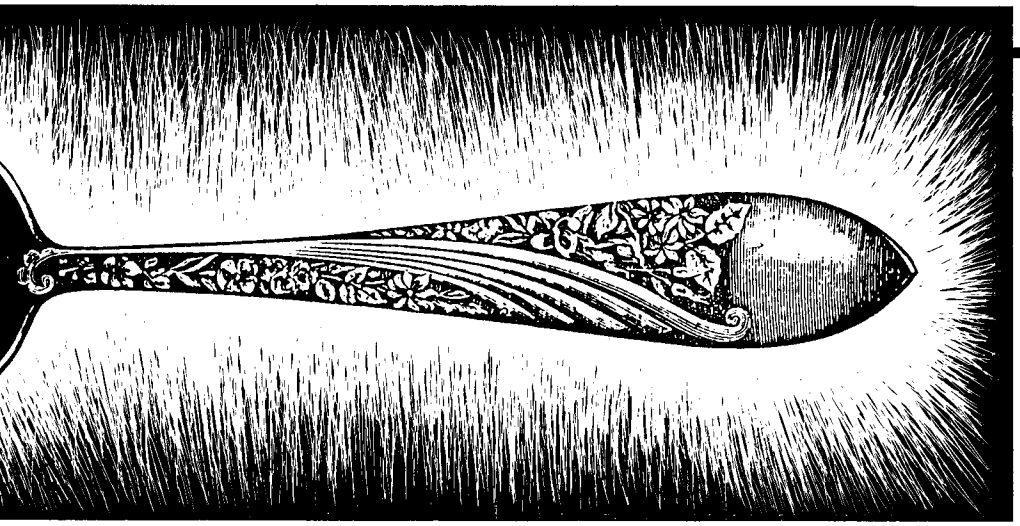
The electrolytic method of separation of a compound into its component elements was pioneered in the early 19th century by Sir Humphry Davy, an English chemist, who had isolated the metals potassium, sodium, calcium, barium, boron, magnesium, and strontium by electrolysis. The electrolytic separation of potassium from one of its salts, say KCl, requires passage of an electric current through molten KCl:

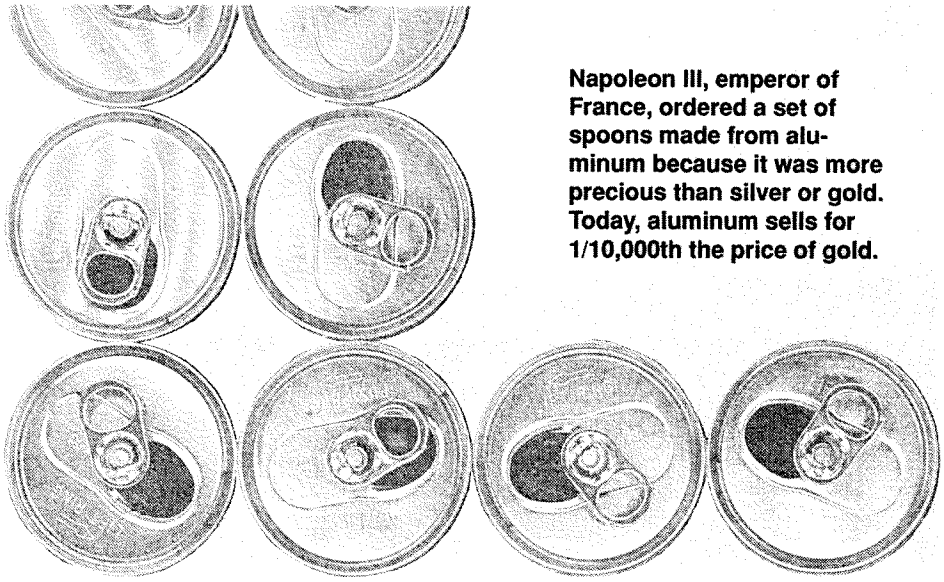
$$2KCl\ (molten) \xrightarrow{\text{electric current}} 2K\ (molten) + Cl_2\ (gas)$$

The electrolytic method seemed to be impractical for aluminum compounds because their melting points are almost inaccessibly high (the melting point of Al_2O_3 is 2000 °C, compared to 776 °C for KCl). Davy suspected that there was an undiscovered metallic element in the mineral alumina and, in 1807, tried to separate the element from the mineral. Even though he failed to isolate the element he gave it the name alumin*um*. Other Europeans adopted the variation alumin*ium*, but Americans still use Davy's original spelling and pronunciation. In 1825 in Copenhagen, H.C. Oersted reported the preparation of aluminum by reacting $AlCl_3$ with a mixture of potassium and iron. What he obtained was not pure aluminum but an alloy or metal mixture. When Wöhler heard of Oersted's work, he repeated it using pure potassium and obtained a small amount of pure aluminum in the form of a gray powder. By 1845, Wöhler was making metallic aluminum particles that he described as being big as pinheads. In 1854, Henri St. Claire Deville, Professor of the Ecole Normale in Paris, improved Wöhler's method and produced lumps of aluminum the size of marbles. He reduced the cost somewhat by using sodium metal instead of potassium in the reaction with aluminum chloride. He also succeeded in producing aluminum by the electrolysis of molten aluminum chloride.

Better than the crown jewels

Deville's work caught the attention of Napoleon III of France who financed further study of aluminum and its methods of preparation. Napoleon had dreams of lightweight helmets and armor for his armies, but the first





Napoleon III, emperor of France, ordered a set of spoons made from aluminum because it was more precious than silver or gold. Today, aluminum sells for 1/10,000th the price of gold.

article fashioned from aluminum was a baby rattle made for the emperor's son. Aluminum was too expensive for everyday use but luxury goods soon followed, including a set of forks and spoons used by honored dignitaries (lesser guests of the emperor had to suffer with tableware of gold or silver). Napoleon III presented his cousin, the King of Denmark, with an aluminum helmet. The public got its first view of aluminum when bars of the new metal were exhibited along with the French crown jewels at the Paris Exposition of 1855. In the United States, the first bars of aluminum were produced in 1856 by Alfred Mounier of Camden, NJ, and were exhibited at the Franklin Institute in Philadelphia. When the Washington Monument was completed in 1884, its apex was capped with a solid aluminum tip weighing 100 oz at $1.10 per oz— the largest piece of aluminum that had ever been cast. Before its installation, it was displayed at Tiffany's in New York.

The production of aluminum depended either directly or indirectly on the production of an electric current for electrolysis. Davy's electricity came from voltaic cells made of zinc and copper, expensive materials that meant high costs for electrolytically produced elements. The electric generator was invented in 1866, permitting the conversion of steam or water power into electricity. This lowered the price of electrolytic separations, but the big advance came in 1886 when Charles Hall in the United States and Paul Heroult in France independently devised a process that freed aluminum electrolytically from the alumina in bauxite ore. Hall and Heroult found that a mixture of Al_2O_3 and cryolite, Na_3AlF_6, has a lower melting point than either alumina or cryolite has separately — just as a mixture of ice and salt melts (or freezes) at a lower temperature than either does independently. The alumina in the molten Al_2O_3–Na_3AlF_6 mixture could then be electrolyzed to produce pure aluminum metal. As production of the metal became more efficient, the price of a pound of aluminum fell from $545 in 1852 to $115 in 1855, to $7 in 1886, and to $0.70 in 1900.

Forgotten foil

This information was interesting, but it didn't solve the mystery of the aluminum foil fragments in my new desk. Were they really made by Wöhler? How did they get to South Carolina? Clearly, they were more the size of Wöhler's pinheads than Deville's lumps. If our specimen did come from Wöhler, as claimed by the aged handwriting, we can date it to between 1845 and 1880; it's probably closer to the earlier date, when he was still interested in aluminum. Wöhler's laboratory in Göttingen was a popular destination for American chemists who went to Germany in the 19th century for advanced study. Perhaps one of Wöhler's American students returned home with a souvenir of his year's study abroad.

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